Coating Method Dependence of Tribological Behaviors in CrAl-coated Zr Cladding

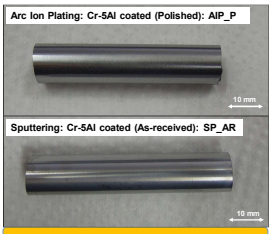
Young-Ho Lee*, Jung-Hwan Park, Dong-Jun Park, Yang-Il Jung, Byoung-Kwon Choi, Sung-Chan Yoo, Hyun-Gil Kim
Advanced 3D Printing Technology Development Division, Korea Atomic Energy Research Institute

Introduction

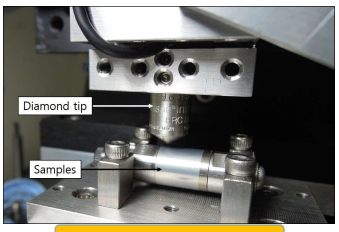
Accident-Tolerant Fuel cladding coated by high corrosion-resistance Alloys (CrAl) under Different coating methods

- Coated claddings with high temperature oxidation resistance alloys
  - one of the strong candidates for accident-tolerant fuel (ATF) claddings
- New materials for surface coating (FeCrAl, SiC/SiC composites)
  - Outstanding corrosion resistance in simulated high temperature steam,
  - Neutron irradiation and dissolution in high temperature water, to be solved for commercial application
- In KAERI, Cr and Cr alloys can be applied as coating materials due to their outstanding oxidation resistance in high temperature steam
  - Selecting coating method for mass production: consideration of economy and safety issues.
  - For example, arc ion plating or cold spray process can be applied to conventional Zr-based fuel claddings without microstructural changes during the coating process.
- From previous test results, physical vapor decompositions can be selected as a process suitable for mass production.
  - Stably deposited on conventional Zr-based claddings without coating damages such as pore, droplet, cracks,
  - Different oxidation resistance and mechanical properties under different coating methods
- In this study, the tribological properties of the Cr-5Al coating layers deposited by an Arc Ion Plating (AIP) and Sputtering (SP) method were experimentally evaluated. Various ATF cladding candidates: FeCrAl, SiC/SiC composites, Cr/CrAl coated Zr alloys, etc.

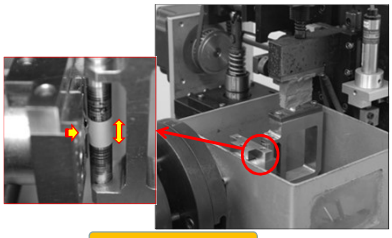
Experiments



Specimen used in this study



Scratch and Indentation test

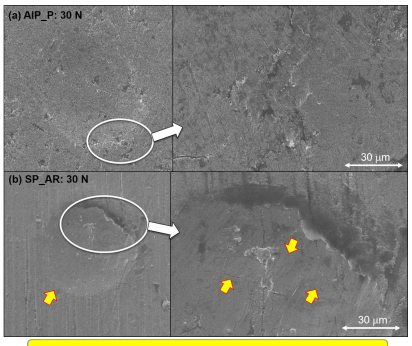

Fretting Wear test

❖ Fretting wear test condition

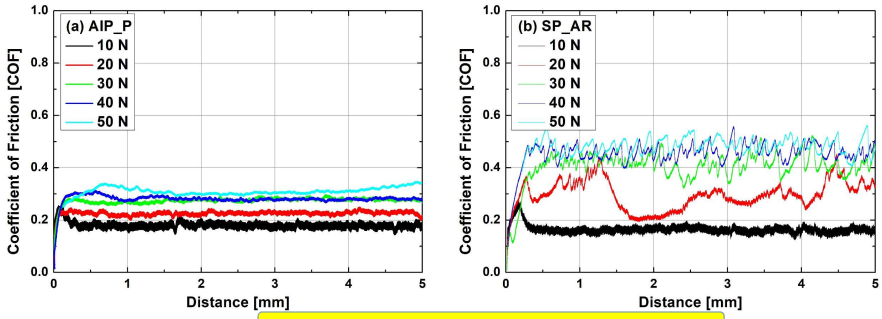
- Normal force: 10 N
- Relative slip amplitude: 100 μm
- Frequency: 30 Hz
- Number of cycles: 10^5~10^6
- Room temperature water

❖ Coated cladding against Zr-based grid specimen with and without surface oxide layer

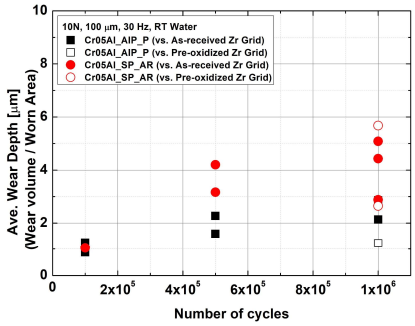
Results & Discussion



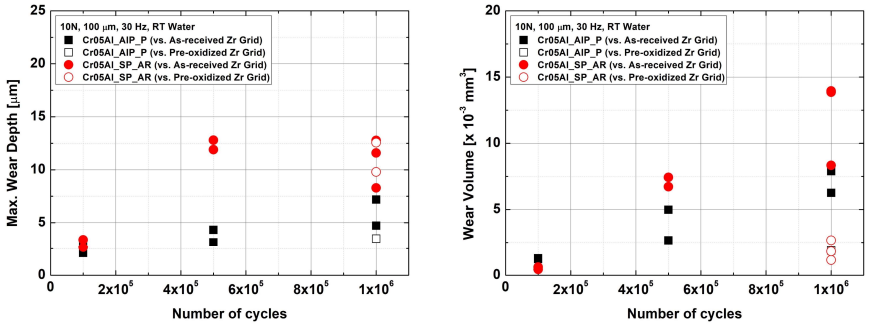
Coating failure mechanism by indentation tests



Frictional behaviors of CrAl coating layer by different coating methods



Average wear depth for considering localized failure by mechanical contacts



Summary of wear test results: (Left) Wear volume, (Right) Maximum wear depth

Summary

In this study, the tribological properties of CrAl-coated fuel claddings by an Arc Ion Plating (AIP) and Sputtering (SP) methods, which have excellent oxidation resistance in high temperature steam, were experimentally evaluated focusing on the effect of different coating methods with the same coating materials.

- From the indentation test, coating layer by the SP method shows well-developed cracks by brittle fractures while that by the AIP method shows negligible cracks by severe plastic deformation.
- The coating layer by the AIP methods was confirmed to be a scratch mechanism similar to cohesive failure due to tensile or conformal cracking by ductile fracture.
- In case of the SP method, however, the recovery spallation behavior was observed in the scratch trace and the adhesive failure could be associated with brittle fracture by interfacial peeling and chipping due to compressive stress.
- Fretting wear resistance of CrAl coating layers showed a strong dependency to the coating methods.

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Advanced 3D Printing Technology Development Division
leeyh@kaeri.re.kr